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The primary purpose of the research funded via AFOSR Grant No. 82-0192 was to establish highly accurate standard stars covering a wide range both in brightness and color around the celestial sphere. The availability of such standard stars would enable anyone to determine the brightness or color of any object projected against the sky from land, the air, or in space. Other secondary projects also were undertaken as circumstances warranted. This document outlines the overall program, including the data acquisition, analysis, and results.

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FAINT PHOTOELECTRIC PHOTOMETRIC STANDARD STAR SEQUENCES

by

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and
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FINAL SCIENTIFIC REPORT

AFOSR GRANT NO. 82-0192

This document contains a summary of the research program undertaken under the auspices of Grant No. 82-0192 from the Air Force Office of Scientific Research (AFOSR). This grant covered the six year time interval 1 January 1982 through 31 December 1987, plus an one hundred eighty day no cost extension, which ended 30 June 1988.

The primary purpose of the research funded via AFOSR Grant No. 82-0192 has been to establish highly accurate standard stars covering a wide range both in brightness and color around the celestial sphere. The availability of such standard stars would enable anyone to determine the brightness or color of any object projected against the sky from land, the air, or in space. During the course of this proposal, new detectors, known as charge coupled devices, became available to the astronomical community. The goals of the program then were expanded to permit the photometric calibration of the sensitivity of the new detectors near their limit of sensitivity. Toward this end, the author searched not only for suitable faint stellar objects but also those of appropriate color combinations. Color enters the picture since a detector's sensitivity usually is a function of wavelength. When one transfers photometric data from an instrumental system to a standard star system, color terms appear in the transformation equations. Hence, faint pairs or groups of stars are needed of as wide a range in color as can be found to help define these color transformation terms. On the surface, this is a straightforward task. The difficulty has been and continues to be in finding such red-blue pairs or groups of stars within the small region on the sky as defined by the area of the detector.

A quite positive comment for this standard star program undertaken with the support of this (82-0192) and a past (77-3218) AFOSR grant is that the standard stars being produced have been adopted as the broad-band photometric standard stars to be used in the calibration of instruments aboard the Hubble Space Telescope (HST). The interest approached the point where the Space Telescope Science Institute (STScI) provided supplemental funding so that the author could hire a postdoctoral fellow to help acquire and analyze the necessary faintest star data.



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A second recognition for this research is that the original standard star paper written by the author (Landolt 1973) has been declared a Science Citation Classic by the Institute for Scientific Information. That recognition reflects that that paper together with those published and in preparation under the auspices of AFOSR support provide the majority of the calibrating stars used in the standardization of broad-band photometry in the world.

I. BACKGROUND TO THE PROGRAM

Astronomical photometry is the observational portion of astronomy that is concerned with the measurement of the energy radiated by celestial objects at any point or points along the electromagnetic spectrum. The measured intensities in the optical region of the spectrum of celestial objects are described by units called magnitudes.

The first attempts to assign brightnesses to celestial objects are lost in antiquity. Hipparchus, an astronomer of the second century B.C., distributed the stars visible to the naked eye into six groups called magnitudes. The brightest naked eye stars were placed into the first magnitude category; those just visible were said to be of magnitude six. It was not until 1856 that N. R. Pogson suggested the now accepted quantitative scale of stellar magnitudes. A difference of five magnitudes in the brightnesses of two celestial objects corresponds to a ratio of one hundred in their luminous flux.

The generally accepted first published collection of stellar brightnesses appeared in the *Almagest*, authored by Ptolemy about 150 A.D. His results, of course, were based on naked eye estimates of the apparent brightnesses of stars. One can obtain differently characterized apparent brightnesses of a celestial object if that brightness is measured through a certain filter whose bandpass permits the passage of radiation from a specified section of the electromagnetic spectrum. The difference in the measured fluxes, or magnitudes, at two different wavelengths is called an object's color index.

As one might expect, the accuracy with which one knows the brightnesses and colors of celestial objects has increased with the passage of time as new techniques have become available. Back around the turn of this century, photography supplanted the naked eye data of all previous ages. The next great change appeared at the end of the Second World War when photomultiplier tubes became available as a still more efficient method of recording incoming radiation from space. The most recent five years or so have seen the advent of charge coupled devices (CCDs) as a new way to detect radiation with still greater efficiency,

and eventually, accuracy. One should note, though, that the earth's atmosphere invokes an ultimate limit upon the accuracies possible for measurements made from the earth's surface.

Each of these detection techniques demands the availability of calibrators with which one can standardize the measurements of flux at specified wavelengths. Modern efforts began with the work of Harold L. Johnson some forty years ago. The standard star work that the author has done over the past twenty years or so has been based upon the foundations established by Johnson and others. Current standardized magnitudes and color indices for a few hundred stars approach the limit of accuracy attainable for the techniques utilized for ground-based observations.

Accurate and readily accessible standard star sequences are necessary for the calibration of the intensity and color data that are collected by observers of celestial phenomena. The most used and long-lived of the photometric systems of the past forty or so years is the UBV photometric system due to Harold L. Johnson and W. W. Morgan (1953). Additional refinements were published by Johnson and Harris (1954) and by Johnson (1955). Later on, under the guidance of Johnson, the UBV photometric system was expanded to longer wavelengths, at 7000 Å (the R band), and 9000 Å (the I band). The results appeared in a paper by Johnson, Mitchell, Iriarte, and Wisniewski (1966) and references therein. These just mentioned papers by Johnson and collaborators contained extensive lists of standard stars which enabled astronomers everywhere to tie into a well-established photometric system. As detectors improved, though, these standard stars proved too bright; the telescope-detector data collection systems could be saturated through their use. In some instances and under some conditions, this meant that a given detector could be destroyed.

The author (Landolt 1973) made an initial attempt to alleviate the 'too bright' standard star situation when he published a list which contained a few hundred stars to be used as standards, the majority of which were in the magnitude range $10.5 < V < 12.5$. These stars, tied into Johnson's original UBV standard stars, covered a color index range $-0.25 < (B-V) < +2.00$. There was not a large number of stars of extreme color, however. The availability of stars of extreme color are needed if one wants to be able to really derive the best color transformation relations. This latter problem was addressed to some extent with a second standard star paper (Landolt 1983a) [see paper no. 4 in the Appendix]. That paper also added intensity measures at the R (6000 Å) and I (8250 Å) effective wavelengths, as defined by Kron, White and Gascoigne (1953) and Cousins (1976). Note that the Kron et al. RI filters have effective wavelengths somewhat shortward of Johnson's, thereby minimizing the effect on photometric data of water vapor features in the earth's atmosphere. Cousins (1976) had set up UBVR1

photometric sequences in the Harvard E-regions at declination -45 degrees, and Landolt's (1983a) R,I measures were based upon that work. The vast majority of Cousins' standard star sequences then and now are too bright for direct application at large telescopes. They do comprise, however, some of the most accurate photometry ever published.

The last several years have seen the author emphasizing data collection for sequences of stars of intermediate brightness, those in the magnitude range $11.5 < V < 14.8$. Attempts also were made to acquire data as faint as $V = 17.5$ magnitude, or so, but lack of adequate large telescope time together with poor sky conditions when the telescope time was available permitted little progress. The last few years have seen the development of CCDs as probably the detector of the future, insofar as faint celestial objects are concerned. The development of CCDs means that one can now acquire data for faint objects projected against the sky with great accuracy and yet not have to have access to the largest telescopes in so doing. The author, therefore, in addition to trying to finish up work on stars of intermediate brightness, has embarked during the last two years or so on an observational program which will extend standard star sequences to the ever fainter limits now reachable by the largest ground-based telescopes and to be reached by space based systems.

II. THE CTIO PROGRAM

The initial portion of this photometric research program was undertaken, and with the support of this grant continued, at the United States funded Cerro Tololo Inter-American Observatory (CTIO) in Chile. A major reason for choosing that site was and is because statistically one finds the best weather conditions for earth-bound astronomical work there. Access to Cousins (1976) RI photometric measures also was necessary. The program was initiated under the auspices of AFOSR grant no. 77-3218. The current research has been a continuation of that project. The goal has been to establish accurate, internally consistent, and readily accessible standard star photometric sequences for the calibration of the intensity and color data that astronomers obtain at the telescope. The plan has been to provide broad-band UBVRI photoelectric photometric standard stars in the magnitude range $7 < V < 21$ over as broad a range in color index as possible. The program stars were located in a band centered on the celestial equator, and therefore are easily accessible to telescopes of all sizes in both hemispheres. The observational data have been tied into the UBV standards of Landolt (1973) and the RI standard stars of Cousins (1976).

The long-term observing plan by necessity focused on a bootstrapping theme. The RI standard stars of Cousins (1976) were too bright for all available telescopes except the CTIO 0.4-m telescope. Therefore, it was necessary to begin the manufacture of the new, and fainter, standard stars at the 0.4-m telescope. Stars made into standard stars at the 0.4-m telescope were used as standard stars at the 0.9-m telescope. Standards established at the 0.9-m telescope were used to calibrate the data obtained at the 1.5-m telescope, and so on, a larger telescope being used at each step of the way.

As the data were being obtained, each telescope was moved through large angular displacements on the sky. At one point in the data analysis, it became apparent that, on some occasions, discrepancies were appearing as a function of the telescope's position on the sky. Study of the situation showed that this error in the final V magnitude could be approximated as a function of declination. Eventually the observed effect was ascribed to an insecure photomultiplier mounting.

In the meantime, however, it was necessary to compare the observational data with "check" stars over a large range in declination, thereby ensuring some knowledge of equipment orientation, and in particular, photomultiplier behavior. These check stars were observed with either a RCA 1P21 or 931 photomultiplier and UBV photometric system filters. The observations were placed on the UBV photometric system defined by Landolt (1973). About ten stars were observed at each right ascension zone at 0h, 6h, 12h, and 18h right ascension and between -75 degrees and +30 degrees declination at the 0.4-m telescope. All stars chosen were about 7th magnitude so that they could be identified easily without the need for finding charts. Since these stars were too bright for safe use of the detectors used at large telescopes, a similar set of declination check stars was established at the 0.9-m telescope at 0h, 8h, and 16h right ascension, and again in the declination range -75 degrees to +30 degrees. There were 48 stars total in the latter group. Since these stars are about 12th magnitude in brightness, they are accessible with care to all but the largest telescope.

The assumption was made that the photometric system which included the 1P21 type photomultiplier was stable. Nearly forty years of use by the astronomical community has indicated such to be the case. The declination check stars at the 0.4-m and 0.9-m CTIO telescopes were observed over a two year time span. The result is an internally consistent set of declination check stars along several hour circles over large angular arcs which can in the future be used to check photomultiplier/coldbox orientation stability. The paper appeared in the Astronomical Journal (Landolt 1983b) [paper no. 6 in the Appendix].

UBVRI photoelectric observations of 223 stars centered in an approximate two degree wide band centered on the celestial equator, and observed at the CTIO 0.4-m and 0.9-m telescopes, resulted from the early efforts in this and the preceding grant. Most of these stars were in the Kapteyn Selected Areas. The stars averaged 20.7 measures each; each star was observed on an average 12.2 different nights. The numerical size of the average weighted mean error of the mean observed magnitude or color index was found to be 0.0029 ± 0.0012 in V , 0.0027 ± 0.0011 in $(B-V)$, 0.0050 ± 0.0026 in $(U-B)$, 0.0020 ± 0.0009 in $(V-R)$, 0.0021 ± 0.0013 in $(R-I)$, and 0.0025 ± 0.0013 in $(V-I)$. These results appeared in Landolt (1983a) [paper no. 4 in the Appendix].

Since the appearance of the just mentioned paper, efforts have been made to achieve the remainder of the goal set out in the original proposal, namely to establish standard stars down to the 17th magnitude. This work was to be done at the CTIO 1.5-m and 4.0-m telescopes. Generous amounts of telescope time were assigned at the 1.5-m telescope, but almost always in too much moonlight. The latter fact prevented the acquisition of accurate data for the fainter stars, particularly in the U and I wavelength bands; the bright moonlit sky background swamped the signal from the star. The 4.0-m telescope time assignments were another problem in that pressure for use of that instrument is immense in the astronomical community. And even though many astronomers need the kind of results that would be forthcoming from a program such as supported in this grant, little support was given for the assignment of the largest telescope's time to the project. The time that was made available was plagued with clouds and too much moonlight. Hence, throughout most of the duration of the grant, few good data were acquired at the 4.0-m telescope.

Table I, which follows, gives an indication of the success with the elements of nature, or the lack thereof, enjoyed by the author at the CTIO during the tenure of this grant. The number of nights column shows that a reasonable number of nights were awarded, but the percent of the nights that were usable was quite low. Hence, progress suffered.

TABLE I

Year	no. nights	usable
1982	38	56%
1983	20	35
1984	18	37
1985	26	62
1986	30	27
1987	29	34

III. THE KPNO PROGRAM

As related in the previous section, the primary observing program involving standard stars at the CTIO encountered apparent stability orientation problems in the photomultipliers early on in the observational program. Check stars were established from far southerly declinations along several hour circles to north of the celestial equator for the purpose of monitoring such instability effects in photometric systems. The response from the astronomical community, once the data were published, indicated the need for a similar project in the northern hemisphere. A proposal for telescope time was awarded long-term status at the Kitt Peak National Observatory (KPNO), and the majority of the needed data were obtained in 1984 and 1985. These data have been reduced, but have been found wanting in quality. A decision will be made shortly whether to try to enhance the data quality, by requesting additional telescope time, or whether to publish the data as they stand. The northern hemisphere check stars pick up where the southern hemisphere stars left off, and continue along the same hour circles up to the vicinity of the north celestial pole.

There exist some three to four dozen stars distributed around the sky which are used to calibrate spectrophotometric data and related instrumentation. The author was requested to provide broad-band UBVRI magnitude and color indices for these stars. Since the majority of them are most easily observable from northern hemisphere sites, most of the data were obtained at the KPNO. Several of the most southerly stars by necessity were observed at the CTIO. Again, long-term status was awarded this project at KPNO. These stars range in brightness from roughly eighth to sixteenth magnitude. One of the stars in the program, G24-9, apparently was caught in the act of fading in intensity (Landolt 1985). Continued monitoring since then, whenever opportunity arose, showed no such additional dramatic action by the star, although it does seem to be variable in brightness. Since the star is a cool white dwarf of spectral type DQ, and since only a few stars of this type are known, the confirmation and understanding of its variation would be of more than passing interest. The observational portion of the broad-band photometric study of these spectrophotometric standard stars was completed in calendar year 1987. Hence, stars heretofore used as standard stars in spectrophotometry have, for the first time, been calibrated thoroughly in a standard broad-band photometric system. Several drafts of the paper which discuss these data have been written; the final draft should be completed soon.

Table II summarizes the telescope time made available at KPNO and the amount of time usable for the projects that have been supported under this grant.

TABLE II

Year	no. nights	usable
1983	4	43%
1984	13	28
1985	21	49
1986	19	37
1987	10	34

IV. THE MWLCO PROGRAM

As the author worked toward the goals of his funded research, it became clear that sufficient quality telescope time was not becoming available. And the time that was assigned was further diluted due to poor weather, and hence poor observing conditions. This set of circumstances particularly held true for the fainter stars. In part, an attempt at solving the dilemma took the approach of using CCDs on the smaller and intermediate sized telescopes where telescope time was more easily available. A second approach was to apply for additional telescope time at a private observatory, in addition to that obtained at the national facilities, CTIO and KPNO. Therefore, telescope time was applied for, and received, at the Mount Wilson and Las Campanas Observatories site on Las Campanas in Chile. Since these telescope assignments took place during the last year of the grant period, one can say little about the results. A large number of nights yielded little good data, but such as they are, the data are being analyzed at the time of writing of this report. The observing statistics are given in Table III.

TABLE III

Year	no. nights	Usable
1987	31	< 30%

V. OTHER PROJECTS

Secondary projects always have been held in readiness throughout the author's observing career because conditions are not always conducive for the acquisition of the highest quality data demanded by the primary program, in the current case, the manufacture of standard stars. Then, too, on occasion it has been

possible to pick up additional telescope time for certain projects. The author particularly has had a unique opportunity to undertake certain long-term monitoring programs since his major programs cover a period of many years. This section reviews a subset of these projects, some by the author himself, and some in collaboration with other astronomers.

i. Two-Star Photometer

Dr. Albert D. Grauer, Professor of Physics and Astronomy at the University of Arkansas in Little Rock (UALR) and Adjunct Professor of Physics and Astronomy at Louisiana State University (LSU) continued to collaborate with the author throughout the grant period. His input concerning instrumentation and photometric problems has been of long-lasting value.

During the time of the first grant (77-3218) and in the initial phase of the current grant (82-0192), Grauer supervised the construction and use of a two-star photometer. Such an instrument permits the simultaneous observation of two stars. The photometer output is then a ratio of the brightness of the two stars at a given wavelength. Since the output is a ratio, the behavior of sky conditions diminishes in importance, and hence one can work in less than ideal climatic conditions.

Through use of the two-star photometer, Grauer discovered that the central star of the planetary nebula Abell 41 is a detached binary star with the then shortest known orbital period (2h 43m). The star represents an important evolutionary link between the wide binaries and the cataclysmic variable stars. This discovery led to several papers by Grauer and collaborators [paper nos. 3, 7, 8, and 18 in the Appendix]. Grauer also discovered that the central star of the planetary nebula Kohoutek 1-16 (K1-16) is a multiply periodic pulsating star with periods ranging from 25 to 30 minutes [paper nos. 14 and 27 in the Appendix]. Since it appears that the period is changing at a rapid rate, Grauer and others continue to follow K 1-16 at the telescope, for such period changes may prove quite important in advancing the understanding of swift changes in stellar evolution via changes in the star's interior structure. Prior to these discoveries, little was known of the photometric characteristics of the central stars of planetary nebulae. Grauer's work has shown that with both single and double stars now known as central stars in planetary nebulae, the planetary nebula phenomenon itself can arise from more than one possible set of circumstances.

Grauer and collaborators also have applied the two star photometry to a study of old hot stars: subdwarfs and white dwarfs [see paper nos. 1, 9, 12, and 25 in the Appendix]. Grauer himself [paper no. 17] found short-term light variations in a

quasar, an observation which constrains the size of the region from which the variation is coming to something like light-minutes rather than the usually conceived huge size of objects associated with quasars.

ii. Galactic Star Clusters

Galactic (or open) star clusters are aggregates of stars which exist in the plane of our Milky Way Galaxy. Photometric studies of star clusters allow one to derive the age, temperature range, metallicity, and luminosity of the stars within them. One can determine the distance and luminosity function of each cluster. Once data have been studied for a sufficient number of star clusters, one can attempt to map and search out elemental abundance gradients within the Galaxy.

Multicolor (wavelength) observations have been accumulated over a period of several years for the galactic star clusters NGC 2437, NGC 2818, NGC 3532, NGC 6192, NGC 7031, van den Bergh Hagen-Harris no. 99, Mel 227, IC 4725, and Cr 359. Data for the cluster IC 2944 have been published (Perry and Landolt 1986).

Although each of these clusters has some characteristic worthy of intensive study, three of them, NGC 2818, NGC 6192, and NGC 7031 especially have attracted the author's interest during the last few years.

NGC 2818 is the only galactic cluster known to the author to contain a planetary nebula (of the same name). [NGC 2437, mentioned above, also has a planetary nebula, NGC 2438, associated with it, but radial velocity studies indicate that the planetary is not a member of NGC 2437.] In the case of NGC 2818, then, one has an opportunity to determine the planetary nebula's distance in an independent way, through knowledge of the star cluster's distance. Further, one can set limits on the age of the planetary nebula via an understanding of the age of the star cluster.

NGC 6192 appears to be a rather heavily reddened galactic cluster whose preliminary color-magnitude diagram most nearly resembles that of the open cluster NGC 6705 (M 11). As such, it appears to be a rather rare type of galactic cluster in that it appears to have more than the usual number of giant stars within its boundary. NGC 2818 and NGC 6192 are southern hemisphere objects which must be studied from CTIO.

NGC 7031 is a northern hemisphere galactic cluster whose potential claim to fame is the apparent association of a supergiant star among its members. If future observations indicate it really is a member, such membership will permit an age constraint for the supergiant. There is some indication in

the published literature that the supergiant is variable in light. Some twenty years of intermittent monitoring of the supergiant's brightness by the author questions the existence of the supposed light variation. [The author became interested in the supergiant many years ago, and started following it photometrically on the chance that the supergiant was a classical cepheid. Had it been a classical cepheid, and were it to be a member of the cluster NGC 7031, one would have had another point on the period-luminosity relation, a basic relation used to determine extra-galactic distances.] Since supergiant stars are known to vary in brightness, it would not be unusual if this one did. If it can be shown that the star is a member of NGC 7031, and if one can make a definitive statement concerning its constancy or variability in light, one can set additional constraints on the evolutionary knowledge of such stars.

The author and his graduate student, Ms. Meenakshi Rao, have been awarded additional telescope time for these three galactic clusters at KPNO and CTIO. These data will form a major portion of the data for Ms. Rao's Ph.D. thesis.

iii. Hydrogen-deficient Stars

Some years ago, the author discovered the variability of several members of a class of star known then as the helium stars; now these objects are called hydrogen-deficient stars. Their atmospheres have lost through evolutionary processes most, if not all, of the hydrogen that they once possessed. The author has continued his photometric study of these stars both by himself, and in conjunction with collaborators. The presence of infrared excesses is an indication of binarity among at least a few members of the class. The light variations appear to have multiple components in their periodicities. These data someday will prove useful as a theorist's probe of the star's interior structure. [Paper nos. 2, 5, 11, 13, 19, and 21 in the Appendix cover this topic. Paper no. 22 is a review paper by the author.]

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Although one always is sorry to see support come to an end, a temporary end, one always hopes, the author wishes to thank everyone at the AFOSR offices who have helped him make a success of the research funded under the auspices of AFOSR grant no. 82-0192. Not all aspects of the research were completed, but most long-term research projects rarely are.

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APPENDIX

The research undertaken under the auspices of this grant involved a years-long observing commitment at the telescopes. There still are many data awaiting additional study which will result in published research papers. The following list is a compilation of the publications which have appeared in press and which have resulted from the AFOSR's support of this research project.

1. "The Noncompact Binary X-Ray Source 4U 2129+47", J. E. McClintock, R. A. London, H. E. Bond, and A. D. Grauer, Astrophysical Journal, 258, 245, 1982.
2. "The Hot Component of KS Persei (HD 30353)", by J. S. Drilling and D. Schoenberger, Astronomy and Astrophysics, 113, L22, 1982.
3. "Abell 41", by A. D. Grauer and H. E. Bond, I.A.U. Circular No. 3714, 1982.

4. "UBVRI Photometric Standard Stars Around the Celestial Equator", by A. U. Landolt, Astronomical Journal, 88, 439, 1983.
5. "On the Nature of Upsilon Sagittarii", by D. Schoenberger and J. S. Drilling, Astrophysical Journal, 268, 225, 1983.
6. "UBVRI Photometry of Stars Useful for Checking Equipment Orientation Stability", by A. U. Landolt, Astronomical Journal, 88, 853, 1983.
7. "The Pre-Cataclysmic Central Star of Abell 41", by A. D. Grauer and H. E. Bond, Bull. Am. Astron. Society, 14, 978, 1983 (Abstract).
8. "The Pre-Cataclysmic Nucleus of Abell 41", by A. D. Grauer and H. E. Bond, Astrophysical Journal, 271, 259, 1983.
9. "The Correlated X-Ray and Optical Time Variability of TT Arietis", by K. A. Jensen, F. A. Cordova, J. Middleditch, K. O. Mason, A. D. Grauer, K. Horne, and R. Gomer, Astrophysical Journal, 270, 211, 1983.
10. "A Search for Light Variations in Barium Stars", by A. U. Landolt, Publ. Astron. Soc. Pacific, 95, 644, 1983.
11. "Broad Band Photometry of Extreme Helium Stars", by J. S. Drilling, A. U. Landolt, and D. S. Schoenberger, Astrophysical Journal, 279, 748, 1984.
12. "Two New Extremely Hot Pulsating White Dwarfs", by H. E. Bond, A. D. Grauer, R. F. Green, and J. W. Liebert, Astrophysical Journal, 279, 751, 1984.
13. "The Elusive Variability of BD +10 2179", by A. D. Grauer, J. S. Drilling, and D. S. Schoenberger, Astron. and Astrophys., 133, 285, 1984.
14. "The Pulsating Central Star of the Planetary Nebula Kohoutek 1-16", by A. D. Grauer and H. E. Bond, Astrophysical Journal, 277, 211, 1984.
15. "Light Variations of the Population II F-Type Supergiant HD 46703", by H. E. Bond, B. W. Carney, and A. D. Grauer, Publ. Astron. Soc. Pacific, 96, 176, 1984.
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2. "UBVRI Photometric Standard Stars in the Magnitude Range $11.5 < V < 14.8$ Around the Celestial Equator", by A. U. Landolt, to be submitted to the Astronomical Journal, 1988.
3. "Optical Multi-color Photometry of Spectrophotometric Standard Stars", by A. U. Landolt, to be submitted to the Astronomical Journal, 1988.
4. "UBVRI Photometry of Stars Useful for Checking Equipment Orientation Stability: The Northern Hemisphere", by A. U. Landolt, to be submitted to the Astronomical Journal, 1989.
5. "Photometry and Periodicities in the Recurrent Nova T Pyxidis", by B. Schaefer and A. U. Landolt, to be submitted to the Astronomical Journal (?), 1989.
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